STUDY OF BOUNDARY LAYER PHENOMENA FOR THIXOTROPIC AND ANTITHIXOTROPIC FLUID: A REVIEW

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Abstract— The study of boundary layer formation for thixotropic and antithixotropic fluid for various geometries is being focused in this paper, as less studies is being focused on the boundary layer development in thixotropic and antithixotropic fluid. As the viscosity of a shear thickening fluid decreases on decreasing shear rate, viscosity at the edge of the boundary layer is zero. In shear thickening fluid the flow out with the boundary layer can remain unaffected by the motion of the wall. The fluid has developed an internal slip surface separating non-communicating regions, due to this reason the study of thixotropic and antithixotropic fluid is become essential.

Keywords: Thixotropic, Anti thixotropic, Boundary Layer

1 Introduction

INTRODUCTION

The name thixotropic is a combination of two Greek words, thixis (shaking or mixing) and trepo (turning or changing), define thixotropic as when there is a reversible isothermal decrease in the rheological properties of system which is clearly depending on the effect of shear deformation or shear stress, the system can be called as thixotropic. Boundary layer is mostly used as one of the most successful phenomena in the history of fluid mechanics, while this statement is true for Newtonian fluids because the conditions made using this approximate theory generally observed that they are suitable for experimental observations. But in the case of non-Newtonian fluids the major resistance is the diversity of the fluid behaviour, each fluid should be studied separately, the nonlinearity introduced by their dependency on shear viscosity leads to the critical mathematical task, this situation much more complex in the fluids when viscosity is time dependent. Time dependency is shown in the laminar region by viscoelastic systems because the microstructure takes time respond to the flow. Phenomena of boundary layer flow is studied and investigated for many years, it used in many fields like chemistry, aero scope and biomedical Engineering. The behaviour of anti thixotropy is defined as the increase in time of viscosity due to shear deformation. Thixotropic behaviour can be understood on the basis of microstructure that depends on the shear history. It is oftenly the result of relatively weak attractive forces between particles.

HISTORY AND ORIGIN

In the early 19th century Schalek and Szegvari [5] concluded from their research that iron oxide gel have the tremendous property of completely becoming gel only by gentle shaking, this shaking leads to the liquefaction of the gel and solidifies again after a period of time, they also found that when this process is performed for number of times there is no such visible deformation in the system. The terminology thixotropy is first given by Peterfi in 1927 [6] in their first paper. „The viscosity of liquid" is given by Emil Hatschek [7] especially they give the chapter on colloidal solutions by 1935. They published a book called „Thixotropic" which is purely dedicated to thixotropy. He becomes the first to introduce the paper in which he described the flow properties of aluminium hydroxide gels.

Thixotropy is described as the reversible changes to a fluid which can flow into an elastic solid gel, while earlier these kinds of changes is attained by varying the temperature, with the property that would melt on heating and then solidifies on heating. The researcher concluded that a new type of phase change was discovered.

PROGRESS

McMillen in 1932[8] done his research work on thixotropic fluids and their behaviour on fluidity which is a function of time. Then Scott Blair[9] did study on number of examples on thixotropic materials like clays, jellies, suspension cream drilling mud etc. and he also done research on thixometers, instrument specially made to analyse the phenomena. He also gives some interesting points that whether we can study the thixotropic fluid at constant shear rate or constant stress.

He also give an overview on the flow of thixotropy, he concluded that the flow in capillary tube of suspensions, given that the migration of particles from the walls is easier to flow in small rather than large tubes due to the phenomena of thixotropy, he prove it by showing that if we double the tube length the flow rate for driving pressure is become half.

Pryce-Jones [10] was the first known rheologist; he studied up to 250 paints using his own device thixometer. He investigated that thixotropy is behave more significantly in non-spherical particles.

Thixotropy is one of the technical terms used in pre-wars; they used the words that time as structural viscosity and false body which now used as shear thinning and extreme shear thinning with thixotropy.

But the full concept of thixotropy behaviour is given by Bauer and Collins in 1967 [11].

"When a reduction in magnitude of rheology properties of a system, such as elastic modulus, yield stress, and viscosity,

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for example occurs reversibly and isothermally with a district time dependence on application of shear strain system is described as thixotropic" this definition is explained in his own words further adding some more conclusion in his works.

DESCRIPTION OF THE PHENOMENA

Every liquid having microstructure shows the property of thixotropy, as thixotropy gives the finite time taken to move from anyone of the stages of microstructure to next and again coming back to the real phase.

Doraiswamy et al [12] give the average size of a suspension in shear as (1) ε is the probability collision of particles. r and ro is the radius shear and unsheared mass of loosely clumped fine particles.

For anti thixotropy, they did an experiment in which 12% volume of phase suspension of inorganic pigment of low molecular polymeric fluid, which grows from 3.4 to 88.1□m, which make to flow from 50 m long tube with dia 0.038m, which meant that the value of ε was as low as 0.0006. From this they concluded that the value will tent to zero above a critical stress.

Anti thixotropy can also be defined as the viscosity for the mass of loosely clumped fine particles can become looser and more open under the action of shear and therefore the viscosity increases.

ENGINEERING CONSEQUENCES OF THIXOTROPY

FLOW IN MIXERS

Edwards et al [13] investigate the behaviour of range of thixotropic material in series of mixers which can be characterised by assuming that the mixer behaviour as it behaves in viscometer, which is operating at the same shear rate as in average shear mixer rate. They used the average shear rate for the flow in cylindrical vessel with anchor, helical ribbon and helical screw impellers, given by the impeller rotational speed N times depends on the geometry of impeller, after the comparisons made between torque produced in the mixer to the signal from a viscometer which is running at the same shear rate, both were halve over the course of the experiment.

FLOWS IN PIPES

Thixotropic liquid when enters a long pipe from a large vessel in which it can be allowed to rest, the velocity and pressure fields which develops is very complex. In the start-up of the flow of thixotropic liquid the large pressure can cause considerable problems in necessary pump performance. Sometimes the cavitation can also be caused which make it unable to initiate the flow which is at rest for some time.

As the flow starts the liquid near the pipe wall is subjected to the highest shear rate but with lowest velocity, it is also subjected to the shear for longer to the fluid which is flowing in the middle of the pipe. This shows very fast break down near the wall, this give rise to low viscosity layer which significantly lubricates the inner, viscous layer. If the pipe is considerably long the steady state profile is established.Whereas for short pipes the flow is complicated with a nonlinear pressure profile.

LITERATURE REVIEW

Sadequi et al [1](2011) observed Blasius flow of thixotropic fluids, laminar two dimensional flow of incompressible thixotropic fluid which obeys Harris rheology model is analysed for a semi finite plate this type of blow behaviour is called as Blassius flow. They assume that

at high Reynolds number the boundary layer theory simplifies to equation of motion. Results show that magnitude and sigh of the material parameters appearing in the fluid model cannot be arbitry, in this work, simplified Harris rheological model is calculated in boundary layer studies of thixotropic fluid, according to the results obtained in their work it is concluded that this fluid model represent thixotropic properties as at least one material properties is time dependent.

Hayat et al [2] (2016) done analysis of thixotropic nanomaterial in a doubly stratified medium considering magnetic field effects. In this work characteristics of double stratification in magneto hydrodynamic (MHD) boundary layer flow of thixotropic nonofluid in presence of mixed convention are reported. The heat generated and absorbed the Brownian motion and thermophoresis effects is also present, by using suitable transformation dimensional nonlinear equation are converted into dimensionless expressions behaviour of the value are quite reverse to each other. The values which are larger for thermal stratification parameter shows higher temperature and thermal boundary layer thickness. Effects of thermophoretic and Brownian motion parameters on nano particles concentration is decreasing. The local Nusselt number values are decreased for larger heat generation parameters.

McArdle et al (2012)[18] done mathematical investigation in the semi-finite fluid or oscillatory boundary condition which is covered by oscillating wall or stokes problem while taking fluid as thixotropic or anti thixotropic. They obtain an asymptotic solution and to enhance the behaviour of the system for large amplitude oscillations. The solution wich is obtain is very much alike for the solution of non-Newtonian fluid. In the case of antthixotropic fluid the fluids reaches zero ta a finite distance from the wall.

Now this study gives the three important and different ways in which the structure of fluid evolve while satisfying periodicity, they verify and extent this results through numerical simulation. Their aim is to explore the full behaviour of the model.

The boundary of the fast and slow adjusting regime depends on the magnitude of the dimensionless amplitude of oscillation and frequency when all these parameters are dimensionless. Study of the stokes problem is one of the simple boundary layer value problem for a viscous fluid which gives the complex nature of the response of structured fluids.

Pitchard et al [19] done investigation on the stokes boundary layer for a power law fluid. They develop half analytical and half similar solution for the oscillatory boundary layer in a half infinite power law bounded by an oscillating walls which is called stokes law problem. These solution differ significantly from the earlier solution for a Newtonian fluid both in sinusoidal form of the velocity oscillation and in the manner at which their amplitude start decreasing with increasing distance from the wall. The velocity reaches zero at a finite distance from the wall and shear thinning fluid decays algebraically with distance. They did numerical that this analytical and similar solution gives approximation to the flow driven by sinusoidal oscillating walls.

Syrakos et al (2015) [3] study the thixotropic flow past a cylinder; in this they study the flow of thixotropic fluid around a cylinder. Bingham constitutive equation is used to describe the fluid by means of structural viscoelastic model. They assumed that the yield stress vary linearly with the structural parameter, from 0 to 1 which means completely broken structure to fully developed skeleton structure. Using finite element method the result is being obtain.in their investigation they fix the value of Reynolds number to 45 so that the flow of recirculation is observed behind the cylinder, but shedding of vortex does not occur, it is observed that the viscous character of the flow can be controlled within certain limits by these parameters disregarding the fact that the Reynolds number is fixed. The breakdown of the structure in the boundary layer and in any of the shear layers, this breakdown effect the drag force on the cylinder as it is directly related to the high rates of strain observed in the boundary layer.

Oishi et al (2016) [20] done investigation on Transient motions of elasto viscoelastic thixotropic materials subjected to an imposed stress field and to stress based free surface boundary conditions. In this paper they give an approach that how to handle the transient flows of elasto viscoelastic thixotropic (EVPT) materials due to the action of gravity force field when subjected to free surface boundary condition that are stress based. This type of motion is common in the problem where the motion is unknown the capability of this work gives how to approach the complexity of the material and the free surface motion, but in this research due to complexity of the material and the problem a number of points cannot be possible to calculate due to complexity.

Pritchard et al (2016) [21] investigate on flow of a thixotropic and anti-thixotropic fluid in a slowly varying channel. In which they use the weakly advective regime.

Governing equation for the slow, steady, two dimensional flow fluid in a channel whose width is slowly varying is constructed. The equation which is used is similar to the equation of classical lubrication theory for Newtonian fluid. They found that the which way the lubrication equation can be simplified in the weakly advective regime where the advection Deborh number is compared to the aspect ratio of the flow and give analytical and semi analytical solution for particular choices of kinetic laws, in which it includes Moore-Mewis-Wanger model and viscoplastic Houska model. In their study they give a developed and provide a systematic lubrication theory for the slow, steady, two dimensional flow of a general thixotropic and anti-thixotropic fluid for a channel which is very slowly. The objective of change in microstructural is in such a way that that flow depends on the magnitude of the advective Deborah number to the aspect ratio of the channel.

In this study they focus on the advective regime which is week, where fluid behaves as a generalised Newtonian fluid .the analysed the thixotropic and non-thixotropic behaviour of fluid in MMW model which contains previous model as special cases.

They developed the lubrication theory for the wide range of thixotropic flow, but this investigation restricted only with the one type of lubrication flows.

Pereira and Pinho (2002) [4], In their work they take the solution of laponite by 1% and blend of 1.5% by weight this work is demonstrated in terms of the rheology and their hydrodynamic behaviour in pipe flows. Oscillatory test is performed on this fluids and it is observed that laponite was shows the behaviour of inelastic but the other fluid shows the elastic behaviour. Small amount in reduction of drag reduction for the laponite fluid. Small amount of drag reduction is measured in turbulent pipe flow, but for the polymer clay the drag reduction is more.

Albegunrin et al (2016) [14] done the comparision between the flow of two non-Newtonian fluids an upper horizontal surface of paraboloid of revolution boundary layer analysis, Non-Newtonian fluid is pass over an upper horizontal surface of a paraboloid of revolution in which the boundary layer phenomena occurs, this is done in the presence of nonlinear thermal radiation. In their study they predict that buoyancy and stretching at the wall create Casson and Wiliamson fluid flow over this kind of surface which is not a perfect horizontal and inclined. The case of unequal coefficient of diffusion of high concentration of catalyst is considered. A transformation equation of similarity is applied so that the governing equation is used to solve the differential equation. Runga Kutta method is used to solve this equation with boundary layer conditions.

Bilingham and Ferguson [22] (1993) done the investigation of Laminar, unidirectional flow of a thixotropic fluid in a circular pipe. In their paper they study the unidirectional axisymmetric flow of a bentonite mud within a circular pipe. Bentonite is an generalised Newtonian fluid which is inelastic. They use a rheological model which determines this behaviour in single parameter which is the measure of the amount of structure in the fluid. They determine this by single rate equation which has a tendency to increase the shear rate. They discovered that for some parameter range the model is not stable, but they eliminate this by introducing diffusion of fluid structure. In monotonic equilibrium it is shown that there is unique stable steady state solution and an approach is being examined to equilibirium.

They also discovered that the model can give rise to nonmonotonic equilibrium. They also concluded that their exists two timescale, one is shearing time scale and longer diffusion time scale.

The model they use to analysie this equation can have an equlibirium shear stress which don‟t depend on shear rates. Whereas the shear stress does not depend on shear rate. And no mechanical stability arises.

Derksen (2011) [15] done simulation of thixotropic fluids.

Rheological properties in the thixotropic liquids depend on the deformation history. The example of clay suspension is an example of thixotropic fluid clay particles form a network. The local viscosity of liquid relates to the integrity of the network. The time dependence of the liquid is due to the finite rate with which the networks builds and breakdown. This concept is used in lattice Boltzmann equation.

On applying this approach to laminar and translational stirred tank flow shows the essential role of liquid time scale on the overall flow behaviour in the tank. Liquid with same steady state but with different time response, which evolved differently towards markedly different steady states.

When studying thixotropic or we can say Non Newtonian fluid flow with rapid growth of the parameter with increasing complexity.

Ebrahimi Et al (2015) [16] done two phase viscous fingering of immiscible thixotropic fluids. A numerical study is used to demonstrate the role played by the time constant used the thixotropic behaviour of a fluid on the viscous, which gives way to prolonged time. In addition they conclude that thixotropic fluid models which are more sophisticated that the Moore model is used to represent thixotropic fluids. The lubrication theory is used to simplify gap averaged governing equation in which the interfacial tension is treated as body force. It is observed that the shapes of fingers are affected by the thixotropic behaviour. The Moore fluid viscosity ratio is also predicted to influence the shapes of the fingerswhich shows zero shear viscosity.

The slip of displacing fluid has a stabilizing effect on viscous fingering phenomena.

Stobiac et al (2013) [17] done investigation on boundary condition for the lattice Boltzmann method in the case of viscous mixing flows. In their research they examine the performance of different boundary condition techniques used for the lattice Boltzmann simulation of viscous mixing flows. They used the three different strategies from the most popular approaches the extrapolation or interpolation and the immersed boundary method. For the order of convergence of the method selected which is implemented on the boundary conditions is verified by the 3 D coquette flow. This investigation purely shows that only the extrapolation method is used for preserving the second order accuracy of the lattice Boltzmann method. Highly parallel method is used to solve the fluid flow with close clearance mixing system. The rate of convergence obtained with different boundary condition is compared on the basis of two characteristics mixing number, the power number and the pumping rate. The result is approximately similar to experimental and finite element method. And at last the influence of the boundary condition on the workload balance and memory usage is analysed, it is observed the immersed boundary condition strategy modifies the parallel efficiency of lattice Boltzmann method, there is no significant effect is observed on memory usage.

CONCLUSION

Due to the growing demands of new technologies examples: micro-electronics, power stations chemical production etc. there is vast requirement to develop novel types of which can be to transfer heat more effectively. Present study will help in to understand the industrial liquid behaviour. As we can say that the above review of the thixotropic fluid can lead to this conclusion that limited study is being focused on the behaviour of thixotropic fluid in different geometries. Limited study is focused on the boundary layer phenomena. There is much more to be studied on the flow pattern of the thixotropic and antthixotropic fluid. As this fluid has a wide scope in industries like of paints, oil etc.

Further studies on the boundary layer phenomena are needed and also the conditions should be evaluated for which the variation in boundary layer observed this can be achieved by varying the geometries.

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